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IMAGE DISPLAY APPARATUS AND METHOD OF DRIVING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to an image display apparatus that displays various images and a method of driving the image display apparatus.

Related Background Art

10 (1) Generally, display images have different aspect ratios (ratios between horizontal sizes and vertical sizes), depending on the types of image sources. The screen sizes
(length-to-width ratios of screens) of image display apparatuses have conventionally been set so as to match
15 the aspect ratios of images to be displayed. As shown in Figs. 1A and 1B, however, there may be cases where the aspect ratios ($x_1:y_1$ and $x_1:y_3$) of screens do not match the aspect ratios ($x_2:y_1$ and $x_1:y_2$) of images. This problem is described in more detail below.

20 It is currently required that image display apparatuses display various types of images, such as television images and Internet images, that have different aspect ratios. Fig. 7A shows an example of an Internet image that is displayed on a personal
25 computer screen and has an aspect ratio of $x_2:y_1=4:3$, while Fig. 7B shows an example of a television image that is displayed on the screen of a wide television

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set and has an aspect ratio of $x_1:y_2=16:9$.

It has conventionally been sufficient that image display apparatuses of television sets only display television images and image display apparatuses of personal computers only display specific images such as Internet images. That is, the aspect ratios of images to be displayed by image display apparatuses have been predetermined and the screen sizes (aspect ratios of screens) of the image display apparatuses have been set to match the aspect ratios of images to be displayed.

Recent advancements in the multimedia field, however, make image display apparatuses not only to display specific images but increases the opportunities for them to display images in various image signal formats. For instance, television sets (image display apparatuses) capable of displaying Internet images and conversely personal computers (image display apparatuses) capable of displaying television images are now on the market. These image display apparatuses are designed not only to display images having a fixed aspect ratio but to display images having various aspect ratios.

Also, there appear television images having various aspect ratios. That is, images broadcasted by terrestrial analog broadcast services have an aspect ratio of 4:3, while images broadcasted by satellite broadcast services or digital broadcast services have

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an aspect ratio of 16:9. This raises the possibility that even if image display apparatuses display only television images and do not display Internet images, images displayed by them vary in the aspect ratio.

5 As shown in Figs. 1A and 1B, if images are displayed by image display apparatuses whose screen sizes do not match the aspect ratios of the images, the screen areas of the image display apparatuses are divided into two types of portions: portions B_1 10 (hereinafter referred to as "effective image areas B_1 ") where various images are displayed, and portions B_2 (hereinafter referred to as "non-effective image areas B_2 ") where no image is displayed and masks are applied. Note that Fig. 1A shows a state where an Internet image 15 (aspect ratio=4:3) is displayed on an image display apparatus whose screen aspect ratio is 16:9, while Fig. 1B shows a state where an image (aspect ratio=16:9) is displayed on an image display apparatus whose screen aspect ratio is 4:3. In either case of these image 20 display apparatuses, black masks are displayed in the non-effective image areas B_2 .

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~~(3) Image display have conventionally been performed by sequentially scanning pixels that are capable of performing multi-level display and are arranged within display screens, although there appear on the market display apparatuses adopting a different display method where image display (multi-level~~

gradation display) is performed by performing time divisional display of each display value subjected to a pulse width modulation (PWM) using pixels for binary display.

5 Fig. 2 shows an example construction of an image display apparatus (projection-type display apparatus using a mono-plate scheme) that performs the time divisional display. Here, the term "mono-plate scheme" means a method of displaying images in each color (such
10 as, red (R), green (G), and blue (B)) using a single spatial modulation element (image display element). This method simplifies optical systems and electric circuit systems and therefore is suitable for realizing a low-cost and lightweight display unit.

15 An image display apparatus 1 in Fig. 2 includes a binary-display-type image display element 2, such as an MEMS (micro-electromechanical systems) spatial modulation element. The image display element 2 is also of a reflection type and reflects light. On the
20 side, toward which the image display element 2 reflects light, are arranged a screen 4, on which images are to be projected, and an optical system 5 for projecting reflection light (light that has been spatially modulated by the image display element 2 and includes
25 display information) onto the screen 4. Note that reference numeral 50 represents a lens.

~~A lighting device 3 is provided with a metal~~

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halide lamp 30 that emits white light using power
supplied by a ballast power source 31. A disc-like
rotary color filter 32 is disposed between the lamp 30
and the image display element 2 so as to be freely
5 rotated and the color filter 32 is structured so as to
be rotated and drove by a filter driving unit 33.
Here, as shown in Fig. 8, the color filter 32 is
divided into three color regions 32R, 32G, and 32B.
Light in three colors (red, green, and blue) are
10 sequentially irradiated onto the image display element
2 according to the rotation of the color filter 32.

Note that reference numeral 34 indicates a lens
disposed between the color filter 32 and the lamp 30,
and numeral 35 indicates a lens disposed between the
15 color filter 32 and the image display element 2.

Also, reference numeral 7 represents an input unit
for inputting image signals. Further, reference
numeral 8 denotes a signal processing unit that
processes the inputted image signals by adjusting image
20 quality (such as brightness, color characteristics, and
gamma characteristics) of the inputted image signals
and converting the adjusted image signals into PWM-
modulated time divisional signals that are appropriate
for the driving method of the display element. The
25 signal processing unit 8 also generates a driving pulse
for the display element, a control signal for a motor,
and the like. Reference numeral 8a indicates a data

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bus that transmits the time divisional signals to the display element, and numeral 8b indicates a control line that transmits the driving pulse to the display element.

5 According to these signals from the signal processing unit 8, the image display element 2 sequentially displays images in synchronization with light irradiation. In this manner, images in different colors are sequentially displayed on the screen 4, on
10 which these images are mixed visually and are recognized as full-color images by viewers.

 The construction of the signal processing unit 8 stated above is described in more detail below with reference to Fig. 9. Here, Fig. 9 is a block diagram
15 showing the detailed construction of the signal processing unit 8.

20 ~~In this drawing, an input unit 7 for inputting various image signals includes an input terminal 71 for inputting an images signal, an input terminal 72 for inputting a horizontal synchronizing signal (IHD) among the input signals, an input terminal 73 for inputting a vertical synchronizing signal (IVD) among the input signals, and an input terminal 74 for inputting a clock signal (ICLK) among the input signals.~~

25 In this drawing, reference numerals 711, 712, 713, and 714 each represent a data bus for transmitting these image signals. Reference numeral 721 indicates a

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Here, the resolution conversion means magnification conversion and interpolation processing that are appropriately performed for an image signal whose resolution does not match the number of display pixels of the image display unit. Also, reference numeral 82 represents a memory unit that provides an image storage area used by the format conversion unit to perform the image processing. Reference numeral 82a indicates a control line group of the memory unit, and numeral 82b indicates a data line group for transferring data between the memory unit and the format conversion unit. Reference numeral 83 denotes a crystal oscillator. According to the clock signal (OCLK) generated by the crystal oscillator, the format conversion unit 81 generates a horizontal synchronizing signal (OHD) and a vertical synchronizing signal (OVD), which are used to establish synchronization after the format conversion processing, under the control by a microcomputer unit (not shown). Reference numeral 811 indicates a signal line for transmitting the horizontal synchronizing signal (OHD), numeral 812 indicates a signal line for transmitting the vertical synchronizing signal (OVD), and numeral 813 indicates a signal line for transmitting the clock signal (OCLK) generated by the crystal oscillator.

Reference numeral 84 represents an image quality adjusting unit that receives the image signal subjected

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to the format conversion and adjusts image quality,
such as brightness, color characteristics, and gamma
characteristics, of images to be displayed on the
display unit, according to the control by the
5 microcomputer (not shown).

Reference numeral 85 indicates a PWM conversion
unit for converting an ordinary image signal for
sequential scanning into a time divisional display
signal by performing the pulse width modulation (PWM),
10 numeral 86 indicates a time divisional sequence storage
unit for storing time divisional drive sequence data
describing the display order and display time period of
the PWM-modulated data, numeral 87 indicates a PWM
driving timing generating unit for generating,
15 according to the time divisional drive sequence,
driving timing used by the PWM conversion unit 85 and
the spatial modulation element (image display element)
that is an image display unit. Reference numeral 861
denotes a transmission line for transmitting the drive
20 sequence data from the time divisional drive sequence
storage unit 86 to the PWM drive timing generating unit
87, and numeral 871 indicates a control line group for
transmitting a driving pulse generated by the PWM
driving timing generating unit 87 and other signals.
25 Also, reference numeral 872 represents an output
terminal via which control signals, such as the driving
pulse, are outputted to the image display element 2,

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numeral 851 a data bus for transmitting the image data converted by the PWM conversion unit 85, and numeral 852 indicates an output terminal via which the image data is outputted to the image display element 2.

5 The PWM drive timing generating unit 87 generates the control signal for the PWM conversion unit 85 and the driving pulse for the display element according to the sequence data in the time divisional sequence storage unit 86. That is, the image inputted into the
10 signal processing unit is subjected to appropriate format conversion and image quality adjustment and then is converted into the time divisional drive signal by the PWM conversion unit 85. The PWM conversion unit 85 and the display element are driven in synchronization
15 with each other.

Fig. 10 shows an example of the display data sequence that has been PWM-modulated by the PWM conversion unit 85. In this drawing, the horizontal axis represents time and reference numeral 201 denotes
20 a start pulse designating the start of image display in each color (R, G, and B) within one field. Reference symbol FR indicates a time period during which red display is performed, reference symbol FG indicates a time period during which green display is performed,
25 and reference symbol FB indicates a time period during which blue display is performed. In this specification, a time period composed of one FR period,

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Also, reference symbols DR1-DR6 represent display data in red that has been PWM-modulated. Here, for ease of explanation, the display data is expressed as 6-bit signal, with reference symbol DR1 representing the first-bit signal, reference symbol DR2 the second-bit signal, reference symbol DR3 the third-bit signal, reference symbol DR4 the fourth-bit signal, reference symbol DR5 the fifth-bit signal, and reference symbol DR6 the sixth-bit signal. The pulse length of each bit signal is twice as long as that of the next lower bit signal. For instance, the length of the second-bit signal DR2 is twice as long as that of the first-bit signal DR1 and the length of the third-bit signal DR3 is twice as long as that of the second-bit signal DR2. According to the image data inputted by the PWM conversion unit 85, each bit is selected so that the pulse width matches the gradation value of the image data. In this manner, a time series ON/OFF signal subjected to the pulse width modulation is obtained. According to this ON/OFF signal, each pixel of the image display element 2 is placed in one of the binary states. By performing light reflection in one of the binary states, an image in red is displayed within one field period according to the integral in the FR period.

In this manner, a full-color image in one field is displayed according to the integral in each color period in one field.

As described above, image (gradation) display in the effective image areas B_1 is performed by placing each pixel of the image display element 2 in one of binary display states according to a pulse train that has been PWM-modulated based on the gradation value of image data in each color. (Here, in this specification, a state where light is reflected is referred to as an "ON state" and a state where light is not reflected is referred to as an "OFF state".) That

is, image display is performed according to the integral of one of binary display states.

Consequently, as distinct from an analog gradation TFT liquid crystal, the state of each pixel of such a
5 binary-type image display element is switched between the ON state and OFF state in one field period even during still image display.

On the other hand, no image is basically displayed in the non-effective image areas B_2 , so that each pixel
10 in these areas B_2 of the binary image display element 2 is continuously placed in the OFF state and dark display is performed. In this example where display data is expressed as 6-bit signal, the dark display corresponds to a situation where each of RGB (red,
15 green, and blue) has shade 0 among 64 (0-63) shades of gray scale.

It should be noted here that an example measure against hinge storage (to be described later) is disclosed in Japanese Patent Application Laid-open No.
20 08-195963.

Also, Japanese Patent Application Laid-open No. 09-322101 discloses a measure against image burn-in (to be described later). This patent application discloses a measure against image burn-in on a CRT caused by
25 still image display. With this technique, the input current into the fluorescent surface of the CRT is maintained basically constant during both of display

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time periods and non-display time periods.

Another conventional technique of preventing image burn-in is disclosed in Japanese Patent Application Laid-open No. 5-153529. This patent application
5 discloses a technique of achieving a liquid crystal display panel, which is easy to view, and of preventing image burn-in on the display panel. In particular, with this technique, white display is performed in side panel areas of the liquid crystal display panel for a
10 predetermined time period before a display operation is stopped.

Japanese Patent Application Laid-open No. 5-122633 discloses still another conventional technique of reducing a brightness unevenness in non-image areas
15 occurring when an image whose aspect ratio is 4:3 is displayed on a wide aspect television set. With this conventional technique, if non-image areas are generated on the screen of a cathode ray tube due to the display of a 4:3 image, light emission is performed
20 in the non-image areas for a time period before the system is turned off, with the time period being determined according to the display time period of the image signal whose aspect ratio is 4:3.

25 SUMMARY OF THE INVENTION

The problem to be solved by the prevent invention is to realize a construction of an image display

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apparatus that suitably suppresses the degradation of the image display apparatus caused when the screen of the image display apparatus is divided into an area in which images are displayed and an area in which no
5 image is displayed.

In effective image areas B_1 on a binary device, the state of each pixel of an image display element is continuously switched between the ON state and the OFF state according to an image signal. In non-effective
10 image areas B_2 , however, the state of each pixel remains in the OFF state, which becomes a cause of the degradation of the image display element. In particular, in the case of an MEMS element that is a binary device performing image display according to the
15 stated time divisional drive scheme, an operation unit that operates by means of micromechanics is mechanically degraded or altered. Also, the operation unit suffers from mechanical malfunctions caused by the changes in mechanics relation with an electrostatic
20 power. For instance, as described in Japanese Patent Application Laid-open No. 8-195963, this phenomenon is known as "hinge storage" in the case of the Texas Instrument's DMD. Such a phenomenon lowers the reliability and image quality of a display element and
25 therefore becomes a critical problem for an image display apparatus adopting the time divisional drive scheme.

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It should be noted here that a situation where there is a difference in aspect ratio (to be precise, a situation where the aspect ratio of a display image differs from that of a screen) is not the sole cause of the non-effective image areas B_2 (dark display portions) on a screen. For instance, if a plurality of sub-screen areas are generated on a single screen, non-effective image areas B_2 are generated between the sub-screen areas.

Also, in addition to the case of monochrome image display, the stated problem similarly arises in the case of full color image display. That is, even in the case where a full color image is displayed, non-effective image areas are generated in some cases. If the non-effective image areas remain in an OFF state for a long time, this also causes the problem stated above.

An object of the present invention is therefore to provide an image display apparatus that is resistant to the stated degradation and image burn-in.

Another object of the present invention is to provide a method of driving an image display apparatus without causing the stated degradation and image burn-in.

An invention disclosed in this specification is constructed as follows.

That is, according to the present invention, there

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is provided an image display apparatus including an image signal generating unit for generating an image signal and an image display element for displaying an image on a screen according to the image signal inputted from the image signal generating unit, characterized in that when the screen is divided into a portion in which the image is displayed and a dark display portion in which no image is displayed, non-dark display is performed in the dark display portion for a very short time period from a start time of display control until a start time of a process for terminating the display control.

Here, the start time of the display control means a time when power supply to the image display element is started to drive the element. Also, the start time of the process for terminating the display control means earlier one of (a) a start time of control for terminating power supply to the image signal generating unit for image display control and (b) a start time of control for terminating the power supply to the image display element for driving the element. For instance, a time when an OFF signal is supplied from a timer or a time when a user designates the termination of an operation state by pushing a button corresponds to the start time of the process for terminating the display control.

According to the present invention, the image

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period, this makes viewers feel visual interferences. Therefore, by repeatedly performing a non-dark display operation for a very short time period, the degradation is suitably suppressed, with viewers rarely feeling visual interferences. As described later, it is preferable that the effective time of one non-dark display operation is set at 4ms or less. Also, it is suitable that the total effective time of the non-dark display repeatedly performed accounts for 20% or less of an entire display period. Here, the image display apparatus may suitably adopt a construction in which the non-dark display is cyclically performed a plurality of times. Also, the image display apparatus may suitably adopt a construction where the non-dark display is performed each time several field periods have passed. In particular, the image display apparatus may suitably adopt a construction where when images are displayed by sequentially irradiating the image display element with light in various colors and switching images in the colors displayed by the image display element in synchronization with the light irradiation, the non-dark display is performed in a display period assigned to a specific color.

It should be noted here that with the stated constructions, dark display is performed in a portion where no images are substantially formed, and non-dark display is performed for a very short time period

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predetermined area for a moment from a start time of display control until a start time of a process for terminating the display control.

Further, this specification contains the following
5 invention.

An image display apparatus including an image
signal generating unit for generating an image signal
and an image display element for displaying images on a
screen by performing bright display and dark display
10 according to the image signal inputted from the image
signal generating unit, characterized in that when the
screen is divided into an effective image area in which
various images are displayed while a non-effective
image area in which no image is displayed, dark display
15 is continuously performed and bright display is
performed for a very short time period in the non-
effective image area.

The stated constructions and methods may be
combined with one another.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B show relations between aspect
ratios of images and aspect ratios of screens;

Fig. 2 shows an example construction of an image
25 display apparatus (a mono-plate projection-type display
apparatus);

Fig. 3 is a block diagram showing the detailed

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construction and the like of a signal processing unit;

Fig. 4 shows a pulse-width-modulated signal
inputted into an image display element;

Fig. 5 is a block diagram showing the detailed
5 construction and the like of a signal processing unit;

Fig. 6 shows a pulse-width-modulated signal
inputted into the image display element;

Figs. 7A and 7B show example aspect ratios of
various images;

10 Fig. 8 shows the shape and the like of a color
filter;

Fig. 9 is a block diagram showing the detailed
construction and the like of still a signal processing
unit;

15 Fig. 10 shows a pulse-width-modulated signal
inputted into the image display element;

Fig. 11 shows an example screen state of an image
display apparatus that is capable of simultaneously
generating a plurality of sub-screen areas;

20 Fig. 12 is a block diagram showing the detailed
construction and the like of a signal processing unit;

Fig. 13A shows a look-up table for image display
element protection;

25 Fig. 13B shows a look-up table for the image
display element protection;

Fig. 14 is a perspective view showing the outline
of the construction of an MEMS element;

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Figs. 15A and 15B are perspective views showing the operation of the MEMS element;

Figs. 16A and 16B show example outside shapes of the MEMS element;

5 Figs. 17A and 17B show the operation and the like of the MEMS element;

Fig. 18 shows the waveform of a voltage applied to a liquid crystal;

10 Fig. 19 shows a characteristic curve showing the relation between the applied voltage and transmittance;

Fig. 20 shows another characteristic curve showing the relation between the applied voltage and transmittance;

15 Fig. 21 shows still another characteristic curve showing the relation between the applied voltage and transmittance; and

Fig. 22 shows the waveform of a voltage applied to a liquid crystal.

20 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention are described below with reference to the drawings.

25 In the effective image areas B_1 described in the section "Related Background Art" of this specification, the state of each pixel of the image display element is continuously switched between the ON state and the OFF state according to image signals. In the non-effective

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25 Also, even if image burn-in prevention control is
performed only when an image display apparatus is
turned off, the opportunity to perform the image burn-

25 Also, even if image burn-in prevention control is
performed only when an image display apparatus is
turned off, the opportunity to perform the image burn-

in prevention control is limited.

In the following embodiments, there are described image display apparatuses, where the above-stated degradation and image burn-in are effectively
5 suppressed, and a driving method for such image display apparatuses.

An embodiment mode of the present invention is described below with reference to Figs. 1A, 1B, 2, 4, and 6.

10 The present invention is applied to the image display apparatus 1 shown in Fig. 2. As shown in this drawing, an image display apparatus 1 includes an image signal generating unit 8 for generating an image signal and an image display element 2 that displays images on
15 a screen according to the image signal inputted from the image signal generating unit 8.

Here, any image display element may be used as the image display element 2 as long as image display is performed using bright/dark display states (binary
20 display states). An example of such is a spatial modulation element of an MEMS (micro-electromechanical systems) type. An example of the MEMS spatial modulation element is an element, such as the Texas Instrument's DMD device, that has a construction shown
25 in Fig. 14 where each pixel is provided with a micromirror 11 that is supported by a shaft so as to be freely swung. In the spatial modulation element, the

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micromirror 11 is made of a conductive material. Also, electrodes 12 and 13 are disposed so as to oppose the mirror 11. The position of the mirror 11 is changed as follows.

5 If the voltage between the mirror 11 and the electrode 13 is higher than that between the mirror 11 and the electrode 12, the mirror 11 is rotated clockwise and is set in a first position C1 shown in Fig. 15A.

10 If the voltage between the mirror 11 and the electrode 12 is higher than that between the mirror 11 and the electrode 13, the mirror 11 is rotated counterclockwise and is set in a second position C2 shown in Fig. 15B.

15 An ordinary example of the image display element 2 is a wide-shaped (rectangular) element where pixels are consecutively arranged vertically and horizontally, as shown in Fig. 16A. Another ordinary example is a narrow and long element where pixels are consecutively
20 arranged only in one direction, as shown in Fig. 16B. Note that in Fig. 16B, the element includes only one row of pixels, although a plurality of pixel rows may be provided as long as the shape of the element is narrow and long.

25 It does not matter whether the image display element has the shape shown in Fig. 16A or the shape shown in Fig. 16B, as long as a lighting device 3 emits

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light toward the image display element 2, as shown in Fig. 2 (see reference symbol L_0 in Figs. 17A and 17B).

In each pixel whose micromirror 11 is set in the first position C1, light is reflected toward a light absorber 20 and dark display is performed, as indicated by reference symbol L_1 (see Figs. 17A and 17B).

In each pixel whose micromirror 11 is set in the second position C2, light is reflected so that bright display is performed, as indicated by reference symbol L_2 (see Figs. 17A and 17B).

Here, in the case of the apparatus shown in Fig. 17A, image display is performed only by projecting reflection light L_2 from the mirror 11 onto a screen 4 through a projection lens 50. However, in the case of the apparatus shown in Fig. 17B, it is required to scan the light to be projected onto the screen 4. In this drawing, a scanning means 21 is disposed on the optical path of the light L_2 reflected by the micromirror 11 so as to scan light L_3 onto the screen 4. Here, any other light scanning method may be used.

In either case of these apparatuses, image display is performed by setting the mirror 11 provided for each pixel in the first position C1 or the second position C2.

Also, in this embodiment mode, the screen area of the image display element 2 is divided into an effective image area B_1 and a non-effective image area

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B₂. In the effective image area B₁, various images are displayed. In the non-effective image area B₂, however, dark display is continuously performed without displaying any image, and bright display is also performed for a very short time period during the dark display. Note that it is preferable that the total of effective times of bright display (non-dark display) occupies a portion exceeding 0% but not exceeding 20% of the entire display time period during which images are substantially displayed in the effective image area (in which image display is performed). Also, it is preferable that the effective time of one non-dark display operation is set not to exceed 4 ms. Here, "the effective time of one non-dark display operation" means the total of time periods during which at least one pixel in the non-effective image areas (dark display areas) is placed in the non-dark state within one image display refresh cycle. The proportion of the total effective time of non-dark display to the entire display time period may be reduced by decreasing the number of fields in which non-dark display is performed. This is effective at implementing the present invention, although attention needs to be paid to the point described below. The following description is based on the assumption that one field time period is set as 17ms. Even if the proportion of the total effective time of non-dark display to the

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entire display time period is reduced by using the entire one field time period as an effective time of non-dark display and by refraining from performing the non-dark display in the following four fields, this makes viewers feel some visual interferences. By reducing the effective time of one non-dark display operation to 4 ms or less, however, the visual interferences felt by viewers can be suitably suppressed. On the other hand, even in the case where the effective time of one non-dark display operation is set at 4 ms or less, if one field time period is set at 10ms and one non-dark display operation with the effective time of 4 ms is performed in each field, a black mask is conspicuously brightened. Accordingly, it is preferable that the effective time of one non-dark display operation is set at 4 ms or less and the total effective time of non-dark display is set to account for 20% or less of the entire display time period.

Here, the situation where the area of a screen is divided into the effective image area B_1 and the non-effective image area B_2 occurs, for instance, if the aspect ratio of an image to be displayed differs from the aspect ratio of the screen, as shown in Figs. 1A and 1B.

Also, it does not matter whether a screen area includes only one effective image area B_1 (portion in

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which image display is performed) or a plurality of effective image areas B_1 .

It should be noted here that gradation images may be displayed with a construction where a PWM-modulated signal is sent from the image signal generating unit 8 to the image display element 2. On receiving the PWM-modulated signal, the image display element 2 is driven according to a time divisional drive sequence to display a gray scale image. In this case, the image signal generating unit 8 converts a multi-level gradation image signal into a PWM-modulated signal.

Here, full-color display based on a so-called field sequential scheme (color sequential switching scheme) may be performed using the image display apparatus 1. That is, the lighting device 3 sequentially emits light in each color toward the image display element 2, the image display element 2 changes images in synchronization with the emission of light, the changed images are recognized as images in respective colors, and the color images are mixed so as to be recognized as a full-color image. In this case, in the non-effective image area B_2 , dark display is continuously performed and bright display is performed for a very short time period during the dark display. It is preferable that this bright display is performed in display periods assigned to a specific color, such as blue. Also, a construction is preferred where the

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display gradation level and display color during bright display are adjustable.

The following description concerns a method of driving the image display apparatus of the present embodiment mode.

In this embodiment mode, if images are displayed in part of a screen area and therefore the screen area is divided into the effective image area B_1 where image display is performed and the non-effective image area B_2 where image display is not performed, image display is performed as follows. The non-effective image area B_2 is placed in one of binary display states to continuously perform black display (OFF state) while image display is being performed in the effective image area B_1 . During (in the middle of) the OFF display state, however, the non-effective image area B_2 is placed in the opposite display state (white display (ON state)) for a very short time period.

Here, the sentence "the non-effective image area B_2 is placed in the opposite display state (white display (ON state)) for a very short time period" in the above description means that the proportion of the period of the ON display state, out of binary display states, is increased to exceed 0%.

Generally, the life span of an image display element is estimated using results of accelerated reliability testing carried out under several

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predetermined conditions. One of these conditions is the ratio (duty ratio) between the period of one of the binary display states and the period of the other of the binary display states. For instance, the duty ratio is expressed as ON/OFF ratio=95/5. Generally, the reliability of an image display element is lowered in accordance with the increase in the difference (expressed by the duty ratio) in length between the ON period and the OFF period.

10 With the present invention, a situation is avoided where the duty ratio becomes 100/0 or 0/100 in the non-effective image area.

 In more detail, the time difference between the ON period and the OFF period is lowered during driving by, for instance, giving gradation or applying color to a level that does not annoy users. It is impossible to indicate the general level that does not annoy users, although it is found from simulation results that it is preferable that the proportion of the display period of the opposite display state, in which the image display element is placed for a very short time period, is set to exceed 0% but not to exceed 20%.

 In usual cases, full-color images are displayed not by faithfully reproducing color tones but by emphasizing blue tone (not green tone and red tone) to a degree. In this manner, images with tinges of blue are displayed. This may be because fluorescent lamps

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Accordingly, in the case where full-color images are displayed, if dark display is continuously performed and blue display (bright display) is performed for a very short time period during the dark display in the non-effective image area B_2 , both of the effective image area B_1 and the non-effective image area B_2 take on blue tinges and therefore users do not have a feeling of wrongness. Note that in countries (such as in the West) where users prefer television images or the like that take on red tinges and have low color temperatures, the setting should be changed so that red display (bright display) is performed for a very short time period during continuous dark display in the non-effective image area B_2 .

It should be noted here that it is not required to perform the reversal of display states in the non-effective image area B_2 throughout the period during which image display is performed in the effective image area B_1 . For instance, while images in the effective image area B_1 are changed each time a unit period (field period) has passed, the reversal of display states may be cyclically performed for a very short time period in the non-effective image area B_2 each time several field periods have passed. This point is described in more

• As indicated by reference symbol Dc1 in Fig. 6, the reversal of display states is performed for a very short time period in a specific field period F_{4n+2} each time four field periods have passed.

• As indicated by reference symbol DB2 in Fig. 4, in the case where color image display is performed with a field sequential scheme described above, the reversal of display states is performed for a very short time period in a display period FB assigned to a specific color.

In these cases, the reversal of display states for a very short time period is performed so as to correspond to each signal related to a low gradation (as indicated by the reference symbol Dc1 in Fig. 6 and the reference symbol DB2 in Fig. 4). By doing so, the degrees of brightness change and color change caused by the reversal of dark display into non-dark display in the non-effective image area B_2 are suppressed to a visual recognition level where users are not annoyed. As a result, the degradation of the element is prevented and the life span of the element is increased without degrading image quality.

25 If the reversal of display states is performed for
a very short time period in specific field periods with
imparting a brightness change under a condition where

the screen refresh frequency is low, this results in flicker phenomenon where brightness changes on the screen are recognized by a viewer. Recently, however, there are many cases where the screen refresh frequency is set at high frequency, such as 120-480Hz, to suppress color cracking phenomenon (color break down phenomenon) that is a problem unique to the color sequential switching scheme. Therefore, by setting the cycle for giving a display element protection signal at 50Hz or higher where flicker is rarely recognized, the protection of a spatial modulation element can be effectively performed without annoying users. Also, even below 50Hz, the protection of a spatial modulation element can be performed without annoying users by reducing the degree of brightness changes or adding white noise.

Consequently, it is preferred that the aforementioned reversal of display states for a very short time period in the non-effective image area B_2 is cyclically performed at a frequency lower than the screen refresh frequency of the image display element 2. It is also preferred that the reversal of display states for a very short time period is cyclically performed at a frequency of 50Hz or higher.

As described above, it is preferred that the proportion of the total effective time of bright display to the entire display period is set to exceed

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0% but not to exceed 20%. Also, it is preferred that the bright display is cyclically performed. For instance, the bright display is cyclically performed each time several field periods have passed. Also, it is preferred that the bright display is cyclically performed at a frequency lower than the screen refresh frequency of the image display element. Further, it is preferred that the bright display is cyclically performed at a frequency of 50Hz or higher.

Here, it is preferable that the screen refresh frequency is 50Hz or higher. As described above, it is preferable that the proportion of the total effective time of bright display to the entire display period is set not to exceed 20%. Therefore, if bright display is performed once in a non-effective image area each time a screen is refreshed, it is preferable that the effective time of one bright display operation is set at $1/50 \times 1/5 = 4$ ms or less. In this case, the condition that the effective time of one bright display operation should be kept at 4 ms or less is also satisfied.

The following description concerns the effects of the present embodiment mode.

In the present embodiment mode, dark display is continuously performed and this display state is reversed into bright display for a very short time period in the non-effective image area B_2 . This suppresses the degradation of the image display element

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time. As a result, the present invention differs from the stated patent application in the object and content.

5 It should be noted here that if the present invention is applied to an MEMS element, the degradation of micromechanical characteristics, such as hinge storage, is prevented, as described above. This effect is described in more detail below.

10 To drive a liquid crystal panel, the polarity of an applied voltage is reversed at certain intervals in general cases (see Fig. 18). This operation is performed to prevent liquid crystal burn-in caused by the bias of an ion distribution within a liquid crystal cell between two electrodes.

15 In the case of a general liquid crystal (a so-called V-shaped liquid crystal), the characteristic curve showing the relation between an applied voltage and transmittance is symmetrical, as shown in Fig. 19. Therefore, if the absolute value of the applied voltage is not changed after the polarity reversal, the
20 transmittance remains constant and display is not affected.

25 On the other hand, in the case of a liquid crystal (a so-called one-side V-shaped liquid crystal) having a characteristic curve shown in Fig. 20, the polarization reversal causes the change in transmittance and the transmittance becomes zero in the case of a negative

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polarity. However, by driving each pixel of a screen in the same manner, the display gradation is not affected (although the brightness of the entire screen is halved).

5 The characteristic curves in Figs. 19 and 20 constantly and gradually changes, so that halftones can be displayed by controlling a voltage. However, in the case of a liquid crystal of a binary display type, such as a ferroelectric liquid crystal or an
10 antiferroelectric liquid crystal, the characteristic curve has a shape shown in Fig. 22 and may exhibit a hysteresis property. In the case where the voltage-transmittance characteristic has a hysteresis property, even if the same black state is displayed, the
15 transmittance varies depending as to which of a white state or a black state is formerly displayed. Therefore, the former image persists like an afterimage and influences the current image. Japanese Patent Application Laid-open Nos. 6-167952 and 6-202078
20 describe a method of preventing the afterimage phenomenon due to the hysteresis by temporarily resetting the entire screen to one of the binary display states. However, this driving method concerns the prevention of the hysteresis problem and therefore
25 does not prevent image burn-in. To prevent image burn-in, it is also required to reverse the polarity of a reset voltage at certain intervals during the

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application of the reset voltage. Fig. 22 shows an example where a voltage is applied to a signal electrode of a liquid crystal display element in this manner. A central voltage V_{com} is a potential of an electrode that opposes a signal electrode, where a liquid crystal layer is sandwiched between these electrodes. V_{sig} is a voltage applied to the signal electrode. A $1F$ period represents a period during which one image is displayed and the applied voltage is reversed in the next $1F'$ period. Display with the same transmittance is performed in both the first $1F$ period and the next $1F'$ period. Fig. 22 concerns the case where display with transmittance of 100% is performed. Also, an R period between the $1F$ period and the $1F'$ period is a reset period and $V_{sig}=V_{com}$ voltage is applied to the signal electrode. Consequently, the potential difference between the electrodes becomes zero and the transmittance also becomes zero in the R period. Like the case shown in Fig. 18, a voltage that is symmetric with respect to V_{com} is applied to the signal electrode in the $1F$ period and the $1F'$ period.

In a liquid crystal, the polarity of an applied voltage is reversed to prevent image burn-in, although it is required to nearly equalize the time period for applying a positive polarity voltage with the time period for applying a negative polarity voltage. However, in the case where the present invention is

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applied to an MEMS element, it is not required to equalize the time period for performing dark display with the time period for performing bright display. If anything, it is required to reduce the bright display time period to 20% or less in order to prevent a situation where viewers visually recognize the bright display. In this respect, the present invention greatly differs from the case of a liquid crystal.

10 <Embodiments>

The present invention is described in more detail below according to embodiments.

(First Embodiment)

15 The present embodiment is described based on the projection-type image display apparatus 1 having the construction shown in Fig. 2. In this drawing, reference numeral 1001 indicates a main power source. When an ON/OFF button 1002 is pushed, the main power source 1001 starts supplying power to the signal processing unit 8 and the image display element 2. 20 When the ON/OFF button 1002 is pushed again, a process for terminating the power supply from the main power source 1001 is started and, in usual cases, the power supply is terminated by this process. The non-dark display (image reversal) in a non-effective image area to be described later is mainly performed between (1) a 25

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time when a user turns on the ON/OFF button 1002 and the power supply to the display element is started and (2) a time when the user pushes the ON/OFF button 1002 again. Note that the overall construction of this display apparatus 1 has already been described and therefore is not explained again here.

The signal processing unit 8 of this embodiment has a construction shown in Fig. 3. This drawing is a block diagram showing the detailed construction and the like of this signal processing unit 8 of the present invention.

An input unit 7 for inputting various input signals includes an input terminal 71 for inputting an image signal, an input terminal 72 for inputting a horizontal synchronizing signal (IHD) among the input signals, an input terminal 73 for inputting a vertical synchronizing signal (IVD) among the input signals, and an input terminal 74 for inputting a clock signal (ICLK) among the input signals.

In this drawing, reference numerals 711, 712, 713, and 714 represent data buses for transmitting the image signals. Reference numeral 721 indicates a signal line for transmitting the horizontal synchronizing signal (IHD) among the input signals, numeral 731 indicates a signal line for transmitting the vertical synchronizing signal (IVD) among the input signals, and numeral 741 indicates a signal line for transmitting the clock

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signal (ICLK) among the input signals.

Reference numeral 80 denotes an image input unit that is an image signal receiving unit. For instance, the image input unit 80 includes a decoder that

5 receives a signal based on a TMDS scheme and decodes the received signal into 24-bit data (three pieces of 8-bit data that respectively correspond to RGB). Here, the TMDS scheme is an image transmission scheme adopted by, for instance, the DVI (Digital Visual Interface)

10 specification published by the standardizing group "DDWG (Digital Display Working Group)". Alternatively, the image input unit 80 includes a decoder that receives a compression signal in an MPEG format via IEEE 1394 and decodes the received compression signal

15 into 24-bit data (three pieces of 8-bit data that respectively correspond to RGB).

Reference numeral 81 represents a format conversion unit that performs resolution conversion, image refresh frequency conversion, non-interlace

20 processing, color matrix conversion, and the like. Here, the resolution conversion includes magnification conversion and interpolation processing that are appropriately performed for an image signal whose resolution does not match the number of display pixels

25 of the image display unit. In this embodiment, the format conversion unit further converts the coordinate area in an image and adds a signal for displaying a

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black frame, so that dark display is performed in the non-effective image area.

Also, reference numeral 82 represents a memory unit that provides an image storage area used by the format conversion unit to perform image processing. Reference numeral 82a indicates a control line group of the memory unit and numeral 82b indicates a data line group for transferring data between the memory unit and the format conversion unit. Reference numeral 83 denotes a crystal oscillator. According to the clock signal (OCLK) generated by the crystal oscillator 83, the format conversion unit 81 generates a horizontal synchronizing signal (OHD) and a vertical synchronizing signal (OVD), which are used to establish synchronization after the format conversion processing, under the control by a microcomputer unit (not shown). Reference numeral 811 indicates a signal line for transmitting the horizontal synchronizing signal (OHD), numeral 812 indicates a signal line for transmitting the vertical synchronizing signal (OVD), and numeral 813 indicates a signal line for transmitting the clock signal (OCLK) generated by the crystal oscillator.

Reference numeral 84 represents an image quality adjusting unit that receives the image signal subjected to the format conversion and adjusts image quality, such as brightness, color characteristics, and gamma characteristics, of images to be displayed on the

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As shown in Fig. 3, a display element protecting signal generator 88 is connected to the image quality adjusting unit 84. The display element protecting signal generator 88 generates a signal for placing pixels in the aforementioned non-effective image area B_2 (in which dark display is performed by the processing of the format conversion unit 81) of the image display element 2 in an ON state for a very short time period without allowing the user to recognize the ON state. As described above, if images having blue tinges are displayed by television sets or the like, users feel that the image quality is superior. Therefore, in this embodiment, the pixels are placed on the ON state only during a period corresponding to the second bit from the least significant bit in each blue sub-field period (see reference symbol DB2 in Fig. 4). In this manner, aside from the black frame display signal added by the format conversion unit 81 to the non-effective image area, the display element protecting signal generator 88 generates a display element protecting signal for placing pixels in the non-effective image area in the ON state only during a period corresponding to the second bit of a blue signal from the least significant bit. Then, the image quality adjusting unit 84 combines the display element protecting signal with the

black frame display signal.

Reference numeral 85 indicates a PWM conversion unit for converting an ordinary image signal for sequential scanning into a time divisional display signal by performing the pulse width modulation (PWM), numeral 86 indicates a time divisional sequence storage unit for storing time divisional drive sequence data describing the display order and display time period of the PWM-modulated data, numeral 87 indicates a PWM drive timing generating unit for generating, according to the time divisional drive sequence, driving timing used by the PWM conversion unit 85 and the spatial modulation element that is an image display unit. Reference numeral 861 denotes a transmission line for transmitting the drive sequence data from the time divisional sequence storage unit 86 to the PWM drive timing generating unit 87, and numeral 871 indicates a control line group for transmitting a driving pulse generated by the PWM drive timing generating unit 87 and other signals. Also, reference numeral 872 represents an output terminal via which control signals, such as the driving pulse, are outputted to the image display element 2, numeral 851 indicates a data bus for transmitting the image data converted by the PWM conversion unit 85, and numeral 852 indicates an output terminal via which the image data is outputted to the image display element 2.

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5 Also, according to experimental results, it is found
that the preferable brightness is 20% or less to
prevent the brightness of the black mask from becoming
an annoying level. This will be described in more
detail later. In the present embodiment, bright
10 display is performed for a very short time period in
the sub-field for blue display. However, the bright
display may be performed in sub-fields corresponding to
all colors. Even if the bright display is performed in
sub-fields for all colors, the brightness of the black
15 mask is not increased to an annoying level because the
effective time of one bright display operation is set
at 173 μ s.

The present embodiment concerns a case where, in a projection-type image display apparatus adopting a color sequential switching scheme, ON display is performed for a bit having a short bit pulse in each sub-field corresponding to one of RGB. However, the present invention is not limited to the color sequential switching scheme and is also applicable to every display apparatus that displays images according to a time divisional drive scheme.

(Second Embodiment)

The present embodiment is described based on the protection-type image display apparatus 1 having the construction shown in Fig. 2. Note that the overall construction of this display apparatus 1 has already
5 been described and therefore is not explained again here.

The signal processing unit 8 of the present embodiment has a construction shown in Fig. 5. Here,
10 Fig. 5 is a block diagram showing the detailed construction and the like of the signal processing unit 8 of the present embodiment.

As distinct from the construction shown in Fig. 3, the present signal processing unit has a construction
15 where the display element protecting signal generator is not connected to the image quality adjusting unit 84. Alternatively, as indicated by reference numeral 89, the display element protecting signal generating unit is connected between the format conversion unit 81
20 and the PWM modulation unit 85. Other constructions in this drawing are the same as those in Fig. 3, and therefore are assigned the same reference numerals and are not described here. The following description centers on differences between these drawings.

25 Like the display element protecting signal generator 89 of the first embodiment, if an image whose aspect ratio differs from that of a display screen is

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to be displayed, the display element protecting signal generating unit 89 generates a signal for placing pixels in a non-effective image area of the image display element in an ON state for a very short time period during a black display operation without allowing a user to recognize the ON state. In this embodiment, the display element protecting signal generator 89 is connected to three signal lines 811, 812, and 813, with a horizontal synchronizing signal (OHD) being inputted via the signal line 811, a vertical synchronizing signal (OVD) being inputted via the signal line 812, and a clock signal (OCLK) generated by the crystal oscillator being inputted via the signal line 813. By counting the number of image output fields outputted from the format conversion unit 81, the display element protecting signal generator 89 generates the display element protecting signal for performing ON display (reversal of binary display states) in the non-effective image area B_2 only for the LSB (least significant bit) period in one of the four fields. This display element protecting signal is transmitted to the PWM conversion unit 85 via the data line 891. Then the PWM conversion unit 85 combines the display element protecting signal with an image signal and subjects the combined signal to the PWM modulation, or combines a PWM-modulated display element protecting signal with a PWM-modulated image signal. In this

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manner, display data is generated and is sent to the display unit.

Fig. 6 shows an example of the display data sequence that has been PWM-modulated by the PWM conversion unit 85. The display data sequence in this drawing corresponds to the non-effective image area B_2 . In this drawing, the horizontal axis represents time and reference numeral 201 denotes a start pulse designating the start of image display in each color of RGB within one field. Also, reference symbol F_{4n} indicates a 4nth field period, reference symbol F_{4n+1} indicates a (4n+1)th field period, reference symbol F_{4n+2} indicates a (4n+2)th field period, and reference symbol F_{4n+3} indicates a (4n+3)th field period.

Reference symbols Da1-Da6, Db1-Db6, Dc1-Dc6, Dd1-Dd6 represent PWM-modulated display data in RGB. In either case of these display data, the pulse length of each bit signal is twice as long as that of the next lower bit signal.

In the present embodiment, ON display is performed in one field out of the four fields, or, more precisely, in the first bit period in the (4n+2)th field period F_{4n+2} , according to the display element protecting signal (as indicated by reference symbol Dc1). Also, OFF display is performed for other signals (that is, all of the remaining bits in the (4n+2)th field period and all bits in other fields). By doing

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so, in the non-effective image area B_2 , completely black frame is not displayed but a black frame having a slight brightness (shade 1 out of 64 shades of gray scale=around 1.5%) is displayed once in each set of four fields. In this manner, the image display element is placed in an ON state of the binary display states for a time period accounting for 0.4% of the entire time period including four successive field periods. As described above, this suppresses the degradation of the image display element 2, improves the reliability and life span of a product, and prevents the degradation of image quality. In more detail, in the case of an MEMS element, the degradation of micromechanical characteristics, such as hinge storage, is prevented.

If one field (one screen refresh period) is set at 60Hz, the effective time of one bright display operation performed in the non-effective image area B_2 becomes $1s/60 \times 1/64 \times 1 = 291 \mu s$.

Here, if brightness is changed in one field in each set of a plurality of fields under a situation where the screen refresh frequency is low, the changes in brightness of the screen is recognized by a viewer (flicker phenomenon occurs). Recently, however, there are many cases where the screen refresh frequency is set at high frequency, such as 120-480Hz, to suppress a color cracking phenomenon (color break down phenomenon)

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that is a problem unique to the color sequential switching scheme. Therefore, by setting the cycle for giving the display element protection signal at 50Hz or higher where flicker is rarely recognized, the protection of a spatial modulation element can be effectively performed without annoying users. Also, even below 50Hz, the protection of a spatial modulation element can be performed without annoying users by reducing the degree of brightness changes or adding white noise.

The present invention is characterized in that if one of the binary display states continues for a long time in an image display element, the current display state is reversed into an opposite display state for a very short time period. Therefore, in addition to a non-effective image area generated when an image whose aspect ratio differs from that of a screen is displayed, the present invention is applicable to various other areas. For instance, the present invention may be applied to a case where a screen area of a display is divided into a plurality of sub-screen areas and there is at least one sub-screen area, in which no image is being displayed. The present invention also may be applied to a mask area, such as a margin area, generated between the sub-screen areas.

Also, if a personal computer continuously displays letters or icons in a window screen or a desk top

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screen, certain pixels of an image display element performing binary display is placed in one of an OFF state and an ON state for a long time. The situation where certain pixels of an image display element is placed in one of an OFF state and an ON state for a long time also arises if still image display is performed for a long time. In these cases, a display apparatus is provided with an image attribute detecting unit that detects the situation where one of an OFF state and an ON state continues for a long time, and operations described in the first and second embodiments are applied to corresponding pixels according to the detection results of the image attribute detecting unit. This realizes an image display apparatus with a high degree of reliability.

The present embodiment has been described based on the projection-type image display apparatus 1 having the construction shown in Fig. 2. However, the present invention is not limited to this and is applicable to various image display apparatuses, such as tri-plate protection-type image display apparatus that uses one spatial modulation element for each color of RGB, as long as the image display apparatuses are driven according to time divisional drive sequences.

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(Third Embodiment)

In the first and second embodiments, the present

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invention is applied to a display apparatus that displays an image signal whose aspect ratio differs from that of a display screen. In the present embodiment, however, the present invention is applied
5 to an image display apparatus that is capable of displaying a plurality of sub-screen areas on a screen.

Fig. 11 shows an example state of a screen of the image display apparatus of the present embodiment.

Reference symbol B3 in this drawing represents a
10 display screen of the image display apparatus of the present embodiment. In this embodiment, the size of the screen is set as 2048 pixels wide by 1536 pixels high. Sub-screen areas B4 and B5 are arbitrary set in the screen area B3 of this image display apparatus.
15 This construction achieves the simultaneous display of a plurality of image signals inputted into the image display apparatus.

Reference symbol B4 indicates a first sub-screen display area in which is displayed an image obtained by
20 a personal computer (hereinafter, "PC") connected to the image display apparatus. The image obtained by the PC has a resolution of XGA (1024 pixels wide by 768 pixels high). Also, reference symbol B5 denotes a second sub-screen display area in which is displayed an
25 image having a resolution of 720 pixels wide by 480 pixels high (suitable resolution for the second sub-screen display area). This image displayed in the

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second sub-screen display area is generated by
converting an HDTV image (1920 pixels wide by 1080
pixels high) that has been obtained by a digital
television tuner connected to the image display
5 apparatus.

Further, reference symbol B6 represents a non-
effective image area in which image display is not
performed. In this embodiment, a user can arbitrary
set a gradation level for data in each color (red,
10 green, and blue) to be displayed in the non-effective
image area of the present image display apparatus. The
user performs this setting operation using a user
setting means including switches provided on the
display apparatus and buttons of a remote controller.
15 As a result, in addition to a general black mask, a
halftone mask and masks colored in various colors (such
as blue and yellow) can also be displayed.

Fig. 12 is a block diagram showing the detailed
construction and the like of the signal processing unit
20 of the present embodiment. In this embodiment, the
overall construction of the display apparatus is almost
the same as that of the projection-type image display
apparatus 1 shown in Fig. 2, although the input unit 7
in Fig. 2 is replaced with two input terminals 71P and
25 71V in Fig. 12 via which image signals are inputted.

In Fig. 12, reference symbol 71P denotes an input
terminal via which an image signal is inputted from the

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PC, and reference symbol 71V an input terminal via which an image signal is inputted from the digital television tuner.

Also, each of reference symbols 711P, 712P, 713P, and 714P represents a data bus for transmitting the image signal inputted from the PC. Further, each of reference symbols 711V, 712V, 713V, and 714V represents a data bus for transmitting the image signal inputted from the digital television tuner.

Reference symbol 80P denotes an image input unit that is a receiving unit for receiving an image signal sent from the PC. For instance, the image input unit 80P includes a decoder that receives a signal based on a TMDS scheme and decodes the received signals into 24-bit data (three pieces of 8-bit data that respectively correspond to RGB). Here, the TMDS scheme is an image transmission scheme adopted by, for instance, the DVI (Digital Visual Interface) specification published by the standardizing group "DDWG (Digital Display Working Group)".

Also, reference symbol 80V denotes an image input unit that is a receiving unit for receiving an image signal sent from the digital television tuner. For instance, the image input unit 80V includes a decoder that receives a compression signal in an MPEG format via IEEE 1394 and decodes the received compression signal into 24-bit data (three pieces of 8-bit data

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that respectively correspond to RGB).

Each of reference numerals 81P and 81V represents a format conversion unit that performs resolution conversion, image refresh frequency conversion, non-interlace processing, color matrix conversion, and the like. Here, the resolution conversion means magnification conversion and interpolation processing that are appropriately performed for image signals whose resolutions do not match the numbers of display pixels in the sub-screen areas of the image display unit.

Also, each of reference symbol 82P and 82V represents a memory unit that provides an image storage area used by one of the format conversion units 81P and 81V to perform image processing. Each of reference numerals 82aP and 82aV indicates a control line group of a corresponding memory unit, and each of reference symbol 82bP and 82bV a data line group for transferring data between a corresponding memory unit and format conversion unit.

Each of reference symbols 84P and 84V represents an image quality adjusting unit that receives the image signal inputted from the PC and the digital television tuner, which is subjected to the format conversion from one of the format conversion units 81P and 81V and adjusts, according to the control by the microcomputer (not shown), image quality, such as brightness, color

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characteristics, and gamma characteristics, of images to be displayed on the display unit.

Reference numeral 90 denotes a user's operating unit including the switches provided on the display apparatus and the buttons of the remote controller. Reference numeral 901 represents a data line for transmitting an operation signal. Reference numeral 91 denotes a non-effective image area data generating unit that generates, according to the operation signal, drawing data values to be displayed in the non-effective image area. Reference numeral 92 indicates a LUT (look-up table) unit for protecting display element. The LUT unit 92 converts values set by a user into appropriate values and outputs the appropriate values to prevent a situation where the display element remains in one of binary display states for a long time. The LUT unit 92 for protecting display element is provided in the non-effective image area data generating unit 91. Reference numeral 902 denotes a data bus for transmitting the non-effective image area data converted by the LUT unit 92.

Reference numeral 93 indicates an image synthesizing unit for generating synthesized image data that represents an image of one screen by combining the non-effective image area data with image data for the sub-screen areas sent from the image quality adjusting units 84P and 84V. Reference numeral 904 represents a

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data bus for transmitting the synthesized image data.

Reference numeral 85 represents a PWM conversion unit for converting an ordinary image signal for sequential scanning into a time divisional display signal by performing the pulse width modulation (PWM), reference numeral 86 a time divisional drive sequence storage unit for storing time divisional drive sequence describing the display order and display time period of the PWM-modulated data, reference numeral 87 a PWM driving timing generating unit for generating, according to the time divisional drive sequence, driving timing used by the PWM conversion unit 85 and the spatial modulation element (image display unit). Reference numeral 861 denotes a transmission line for transmitting the drive sequence data from the time divisional drive sequence storage unit 86 to the PWM driving timing generating unit 87, and reference numeral 871 a control line group for transmitting a driving pulse generated by the PWM driving timing generating unit 87 and other signals. Also, reference numeral 872 represents an output terminal via which control signals, such as the driving pulse, are outputted to the image display element 2, numeral 851 a data bus for transmitting the image data converted by the PWM conversion unit 85, and numeral 852 an output terminal via which the image data is outputted to the image display element 2.

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Here, like in the first and second embodiments, the signal processing unit of the present embodiment includes the input terminals and signal lines for the horizontal synchronizing signal (IHD), vertical
5 synchronizing signal (IVD), and clock signal (ICLK) that are input signals. The signal processing unit of the present embodiment also includes the crystal oscillator and the signal lines for transmitting the horizontal synchronizing signal (OHD) and vertical
10 synchronizing signal (OVD), which are used to establish synchronization after the format conversion processing, and the clock signal (OCLK) generated by the crystal oscillator. However, for ease of explanation, these construction elements are not described here and are
15 not shown in Fig. 12.

Each of Figs. 13A and 13B shows an example of the look-up table used by the LUT unit 92 for protecting display element. Fig. 13A shows a look-up table applied to chrominance data corresponding to R (red)
20 and G (green), out of three primary color data. On the other hand, Fig. 13B shows a look-up table applied to chrominance data corresponding to B (blue). In these drawings, each of the input data value and output data value for each color is in a range from shade 0 to
25 shade 63 (64 shades of gray).

In Fig. 13A, if the input value corresponding to R and G is in a range from shade 1 to shade 60, the

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output value becomes the same as the input value,
although the output value is restricted not to fall
below shade 1 and exceed shade 60. On the other hand,
in Fig. 13B, if the input value corresponding to B is
5 in a range from shade 3 to shade 62, the output value
becomes the same as the input value, although the
output value is restricted not to fall below shade 3
and exceed shade 62.

Consequently, if a user tries to set arbitrary
10 display values in the non-effective image area B6 other
than the sub-screen areas to obtain an intended color
or gradation value, data conversion is internally
performed to protect the display element in the manner
described below.

15 The following description is based on the
assumption that the number of shades of each color
(red, green, and blue) is 64 ranging from shade 0 to
shade 63. In this case, if a user designates the
display of a pure black mask using the user's operating
20 unit, input value data (red=shade 0, green=shade 0,
blue=shade 0) is inputted into the LUT unit 92, which
then outputs an output value (red=shade 1, green=shade
1, blue=shade 3). In this case, the display state of
the display element in the non-effective image area
25 becomes as follows. The non-effective image area is
placed in an ON state for a time period accounting for
1.6% of the entire display period for red and green and

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is placed in an OFF state for a time period accounting for 98.4% of the entire display period. Also, the non-effective image area is placed in an ON state for a time period accounting for 4.7% of the entire display period for blue and is placed in an OFF state for a time period accounting for 95.3% of the entire display period. Accordingly, the display element is placed in the ON state for a time period accounting for 2.6% of one field period on average. This prevents a situation where only one of binary display states continues for a long time (the display element is not placed in the ON state at all). Also, according to experimental results and the like, it is found that if the non-effective image area is placed in the ON state for a time period accounting for 20% or more of one field period, this allows the user to easily recognize a situation where the black mask is brightened. In this embodiment, however, by reducing the proportion of the ON state to around 2.6%, the degradation of image quality recognized by the user can be suppressed. In this manner, despite the fact that the black mask in the non-effective image area has a value where black is slightly brightened, the reliability of the apparatus is ensured without significantly degrading image quality by displaying a black mask with a tinge of blue that users somewhat prefer.

If a user designates the display of a mask in pure

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white using the user's operating unit, input value data (red=shade 63, green=shade 63, blue=shade 63) is inputted into the LUT unit 92, which then outputs an output value (red=shade 60, green=shade 60, blue=shade 62). In this case, the display state of the display element in the non-effective image area becomes as follows. The non-effective image area is placed in an ON state for a time period accounting for 95.3% of the entire display period for red and green and is placed in an OFF state for a time period accounting for 4.7% of the entire display period. Also, the non-effective image area is placed in an ON state for a time period accounting for 98.4% of the entire display period for blue and is placed in an OFF state for a time period accounting for 1.6% of the entire display period. Accordingly, the display element is placed in the OFF state for a time period accounting for 3.7% of one field period on average. This prevents a situation where only one of binary display states continues for a long time (the display element is not placed in the OFF state at all). Here, if the non-effective image area is placed in the OFF state for a time period accounting for 20% or more of one field period, this allows the user to easily recognize the reduced brightness of white. In this embodiment, however, by reducing the proportion of the OFF state to around 3.7%, the degradation of image quality recognized by the user can

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be suppressed.

In this manner, despite the fact that the non-effective image area has a value where white is slightly darkened, the reliability of the apparatus is ensured without significantly degrading image quality by displaying a white mask with a tinge of blue having a high color temperature that users somewhat prefer.

Also, if a user designates the display of a mask in blue using the user's operating unit, input value data (red=shade 0, green=shade 0, blue=shade 63) is inputted into the LUT unit 92, which then outputs an output value (red=shade 1, green=shade 1, blue=shade 62). In this case, the display state of the display element in the non-effective image area becomes as follows. The non-effective image area is placed in an ON state for a time period accounting for 3.1% of the entire display period for red and green and is placed in an OFF state for a time period accounting for 96.9% of the entire display period. Also, the non-effective image area is placed in an ON state for a time period accounting for around 98.4% of the entire display period for blue and is placed in an OFF state for a time period accounting for 1.6% of the entire display period. In the case of a mono-plate projection-type display apparatus (an example thereof is shown in Fig. 2) adopting a color sequential scheme (color field sequential scheme) where display in each color is

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exceed 0%.

Also, in consideration of image quality, it is preferred that the proportion of the total of effective times of the reverse display state among the binary display states in the non-effective image area is set to exceed 0% but not to exceed 20%.

In this embodiment, a look-up table is used to regulate the total effective time of the reverse display state in the non-effective image area among the binary display states in the non-effective image area so as to account for a predetermined proportion of the entire display period. However, a limiter circuit that converts an input value that exceeds or falls below a predetermined value into an appropriate output value may be used instead of the look-up table. Also, a calculation circuit that performs calculation for a value set by a user and determines an output value may be used instead of the look-up table. That is, any other means may be used instead of the look-up table so long as it is possible to regulate the display state of a display element.

In the aforementioned embodiments, a situation where a non-effective image area continuously remains in a dark display state is avoided by reversing the dark display state into a bright display state (non-dark display state) for a very short time period. This suppresses the degradation of an image display element,

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improves the reliability and life span of a product,
and prevents the degradation of image quality. In more
detail, in the case of an MEMS element, the degradation
of micromechanical characteristics, such as hinge
5 storage, is prevented.

As described above, according to the invention of
the present application, the degradation of
construction elements of an image display apparatus is
suitably suppressed.

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